

# DISCRIMINATED RESPONSE AND INCENTIVE PROCESSES IN OPERANT CONDITIONING: A TWO-FACTOR MODEL OF STIMULUS CONTROL<sup>1</sup>

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Understanding stimulus control generated in instrumental learning requires the direct investigation of discriminated response and reinforcer (incentive) processes acquired exclusively through the response-reinforcer contingencies operating on complex (multicomponent) baselines. Two series of stimulus-compounding studies accomplished this direct investigation. In one series, the independent variable was the relative reinforcement between schedule components; in the second series, it was relative response rate between components. Stimulus-compounding tests revealed that response and incentive processes enhanced each other when in agreement, counteracted each other when in opposition, and produced intermediate results when only one factor was operating. This pattern of results led to the conclusion that these factors were algebraically combining and to the development of a response/incentive matrix reflecting these dynamics. This two-factor analysis was extended to the peak-shift effect in stimulus generalization experiments and to the generation of inhibitory control. Two decades of stimulus compounding and peak-shift research were organized within this two-factor framework, extending this traditional approach to learning to active research areas heretofore not systematically considered in these terms.

*Key words:* stimulus control, stimulus compounding, stimulus generalization, incentive, summation, peak shift, inhibition, transfer of control

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Instrumental learning is operationally de-  
fined by the relationship between a response  
and its consequences, *i.e.*, the response-rein-  
forcer (R-S<sup>R</sup>) contingency (Ferster and Skinner,  
1957). However, when responses produce re-

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inforcement during one discriminative stimulus ( $S^D$ ) and not in another, we can point to two resultant associative processes. One is related to the operant responses emitted during an  $S^D$ , and the second to the changes in reinforcement probability produced by these responses. Therefore, stimulus-response (S-R) and stimulus-reinforcer (S- $S^R$ ) relationships can be identified within the stimulus-response-reinforcer (S-R- $S^R$ ) regularities resulting from discriminative operant training.

That response and reinforcer associations can be conditioned to an  $S^D$  has long been emphasized by "two-process" learning theorists (Mowrer, 1947; Rescorla and Solomon, 1967; Schlosberg, 1937), who recognized that the S- $S^R$  arrangement embedded in discriminative instrumental learning resembled the classical conditioning paradigm. However, isolating the contribution of each factor *within* the operant situation itself has been difficult because response and reinforcement rates customarily covary during an  $S^D$ . To surmount this problem, the influence of the embedded S- $S^R$  arrangement has been inferred from transfer-of-control experiments where the classical conditioning investigated is traditionally acquired off the operant baseline (Trapold and Overmier, 1972). However, one must be cautious in generalizing from these studies to the acquisition and operation of S- $S^R$  associations acquired exclusively through instrumental contingencies because of the many procedural differences between the two (Gormezano and Kehoe, 1975; Overmier and Seligman, 1967). In the research program described in this paper, each of these factors, S-R and S- $S^R$ , was independently manipulated solely through the R- $S^R$  contingencies operating within the discriminative stimuli comprising three-component schedules of reinforcement. A two-factor combinational model was induced from the resulting data. It specifies how these S-R and S- $S^R$  (incentive) factors determine the results of free-operant stimulus compounding, and further suggests how these same factors might determine the likelihood of peak-shift on a generalization test.

## STIMULUS COMPOUNDING

When two independently conditioned stimuli are presented simultaneously, stimulus compounding results. During compounding, the rate controlled by the compound is compared to that emitted to the single stimuli. This comparison enables measurement of the control conditioned to each of the stimuli (Hearst, Besley, and Farthing, 1970; Pavlov, 1927; Rescorla, 1969; Weiss, 1972) and inferences about the mechanisms of habit integration.

The original free-operant stimulus compounding studies were independently performed by Wolf (1963) and Weiss (1964). Bar pressing was maintained in tone and in light by intermittent (variable interval) food reinforcement; in the absence of tone and light (T+L) extinction was in effect. In testing, tone-plus-light (T+L) was presented for the first time. This stimulus configuration controlled significantly more responses than did tone or light individually. This robust phenomenon is called additive summation. Three other possible outcomes of stimulus compounding are: (1) the compound might control less responding than the single stimuli (subtractive summation), (2) the compound might control a rate intermediate to those of the single stimuli (response averaging), or (3) the rates emitted to the single and compound stimuli might be comparable.

The additive summation reported by Weiss and Wolf can be adequately explained by attending exclusively to the S-R or S- $S^R$  relationship resulting from the R- $S^R$  contingencies. For example, through the R- $S^R$  contingency effective in tone and in light, each of these stimuli came to control higher rates than T+L, so that more responding might occur in the presence of two stimuli discriminative for an increase in rate (T+L) than to one (tone or light). Or, taking a motivational approach emphasizing S- $S^R$  relations, two reinforcement-associated stimuli might maintain more responding than one. This is essentially an explanation in terms of the energizing effects on behavior of incentive motivational properties conditioned to stimuli through their differential association with reinforcement (Logan, 1960; Mowrer, 1960; Spence, 1956). These effects have also been demonstrated in research concerned with chained

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schedules (Kelleher and Gollub, 1962), acquired drives (Miller, 1948), and conditioned reinforcement (Dinsmoor, 1950).

Covariation of response and reinforcement rates makes the cause of the summative resultant indeterminate. It can be equally well explained by attending exclusively to habit or motivational mechanisms. The problems in behavioral analysis posed by this indeterminacy were the catalyst for a series of researches to separate this covariation.

### RESPONSE AND INCENTIVE ASSAYS

Response rate in tone and in light compared to that in  $\bar{T}+\bar{L}$  measures the response association conditioned to the former stimuli. This means that a tone or light controlling 10 responses per minute would be associated with an increase in rate when  $\bar{T}+\bar{L}$  maintained only five responses per minute, and a decrease in rate when  $\bar{T}+\bar{L}$  maintained 20 responses per minute. Cumulative records would reveal whether these rates represented a stable and regular behavior during these stimuli or a mix of widely different rates. In the studies to be described, tone and light each maintained reasonably stable behaviors that commenced with stimulus onset and changed abruptly when the tone or light was turned off. This abrupt behavioral change assures that differential rates were under exteroceptive stimulus control, rather than local changes in density of reinforcement.

Often, the conditioned incentive value of particular multiple-schedule components can be directly related to the relative probability of reinforcement in their presence. However, this is true only when all other response, discrimination, temporal, and contingency factors are kept comparable over components. Besides reinforcement probability, factors such as schedule requirements (Sheridan, Levinson, and Cristal, 1965; Thompson, 1965), delay of reinforcement (Chung and Herrnstein, 1967), reinforcement magnitude (Cattania, 1963; De Villiers and Millenson, 1972), effortfulness (Lawrence and Festinger, 1962; Lewis, 1964, 1965; Solomon, 1948) and reinforcement predictability (Badia and Culbertson, 1972) or periodicity (Herrnstein, 1964a) can influence reinforcement value in the instrumental situation. Thus, measures of rein-

forcement association that reflect only the difference in probability of reinforcement in the presence of a stimulus as compared to its absence, as formulated by Gibbon, Berryman, and Thompson (1974), are incomplete here.

Determining the reinforcement value acquired by a schedule component requires a psychological measure reflecting the organism's integration of all these influences. Component preference could serve this function. Brown (1961) and Logan and Wagner (1965) claimed that a subject's preference between goal objects should indicate which has the greater incentive and reinforcement value. Translating that to compounding studies, we are interested in preference for tone and light schedule components relative to  $\bar{T}+\bar{L}$ . Of course, whether component preference is interpreted as reflecting an increase or decrease in relative incentive depends on whether responding is being maintained by positive or negative reinforcement.

When responding is maintained by positive reinforcement on a multiple schedule, the preferred schedule component should possess a greater conditioned incentive value than a less preferred component. This is shown in the positive reinforcement column of Table 1. In the upper-left cell, where incentive is indicated as increasing when stimuli change from  $\bar{T}+\bar{L}$  to tone or light, the latter stimuli would be preferred to  $\bar{T}+\bar{L}$ . In the lower-left cell, the reverse is true. If the incentive conditioned to tone and light is lower than that in  $\bar{T}+\bar{L}$ ,  $\bar{T}+\bar{L}$  should be the preferred stimulus. When tone and light each have an incentive value equal to  $\bar{T}+\bar{L}$ , there should be no preference among them.

Table 1  
Incentive Assay  
(Preference for tone and for light compared to  $T+L$ )

Incentive Change (Tone and Light Relative to $\bar{T}+\bar{L}$ )	Reinforcement Maintaining Responding in Tone and Light	
	Positive	Negative
	Tone Light	Tone Light
	Tone Light	Tone Light
Increase	> $\bar{T}+\bar{L}$	< $\bar{T}+\bar{L}$
None	= $\bar{T}+\bar{L}$	= $\bar{T}+\bar{L}$
Decrease	< $\bar{T}+\bar{L}$	> $\bar{T}+\bar{L}$

The right column of Table 1 shows anticipated preferences when responding in tone and in light is maintained by negative reinforcement. In this case, the nonpreferred schedule component possesses the greater negative incentive value. The right column of Table 1 is the mirror image of the left column. When one class of reinforcer (positive or negative) maintains responding in one component of a multiple schedule while the other class maintains responding in the second component, both components would be associated with an incentive increase. Measures of conditioned reinforcement, such as the concurrent chained schedules employed by Autor (1969) and Herrnstein (1964b), or the multiple schedules, where the subject can advance components (Weiss, 1976, Experiment 2, 1977), serve as incentive assays.

#### BASELINES THAT SEPARATE THE COVARIATION OF RESPONSE AND REINFORCEMENT RATES CONDITIONED TO AN SP

##### *Comparable Response-Rate Differences between Schedule Components: Manipulation of Between-Component Reinforcement Differences*

The following studies were similar in several respects. All used rats as subjects and bar pressing as the response. All baselines were composed of three stimulus components: tone, light, and their simultaneous absence ( $\bar{T}+\bar{L}$ ). Finally, tone and light each controlled moderate rates of response while responding ceased in  $\bar{T}+\bar{L}$ . The baselines were differentiated by the proportion of total session reinforcements received in tone, light, and  $\bar{T}+\bar{L}$  components. While tone and light each always controlled an increase in responding, on the different baselines they were associated with (a) an increase in reinforcement, (b) no change in reinforcement, or (c) a reduction in reinforcement.

(a) When tone and light were correlated with a variable-interval (VI) food reinforcement schedule and responses had no scheduled consequences in  $\bar{T}+\bar{L}$ : (1) all reinforcements were received in tone and light components, and (2) these stimuli controlled higher response rates than  $\bar{T}+\bar{L}$ . [See Figure 1 of Weiss (1969) and Figure 4 of Weiss

(1971).] Holz, Azrin, and Ayllon (1963) showed that subjects prefer VI over extinction, indicating that on the multiple VI EXT schedules described above, tone and light would each be associated with an incentive increase.

(b) When tone and light were correlated with a VI schedule, while in  $\bar{T}+\bar{L}$  food was delivered for nonresponding: (1) probability of reinforcement was comparable in tone, light, and  $\bar{T}+\bar{L}$ , and (2) tone and light each controlled higher response rates than  $\bar{T}+\bar{L}$ . [See Figure 4 of Weiss (1971) and Figure 1 of Weiss and Van Ost (1974).] Under this multiple VI DRO schedule, tone and light did not convey information about change in reinforcement probability (see Weiss and Van Ost, 1974, Table 1). Therefore, the subjects should not have formed the classical associations that are considered responsible for the conditioning of differential motivational properties (Rescorla, 1972). Consistent with this is the finding by Herrnstein (1964b) of minimal preference between the reinforcement schedules he assayed when reinforcement rates were equated.

(c) When responding in tone or light did not produce a primary reinforcer, but instead produced  $\bar{T}+\bar{L}$  on a VI schedule, and food reinforcement was delivered for nonresponding in  $\bar{T}+\bar{L}$ : (1) tone and light were each discriminative for a response increase, while (2) these stimuli simultaneously signalled a reduction to zero in the probability of receiving food. Records of performance on this chained VI DRO schedule are given in Figure 1 and Table 1 of Weiss and Van Ost (1974). Preference data indicate that the terminal links of a chained schedule are preferred to links further removed from primary reinforcement (Duncan and Fantino, 1972). Thus, tone and light would here have a lower incentive value than  $\bar{T}+\bar{L}$ .

After responding stabilized, a stimulus compounding test was administered where  $T+L$  was presented for the first time. These results are presented in Figure 1. After multiple VI EXT training (point A,B),  $T+L$  controlled 62.5% of the total test responses emitted to tone, light, and  $T+L$ . This almost 3:1 superiority in responding to  $T+L$  over tone or light is powerful additive summation. Following multiple VI DRO training (point B,C of Figure 1)  $T+L$  controlled only 46.5% of the total test responses. This roughly 2:1

rate superiority of T+L over tone or light alone represents clear additive summation, but significantly less than occurred after multiple VI EXT training. The chained VI DRO animals received none of their reinforcements in tone or light, meaning that T+L was composed of stimuli discriminative for a response increase but associated with a reinforcement decrease. For these animals, T+L controlled 27.4% of the test responses, a percentage comparable to that emitted to tone and light alone.

**Summary.** The results presented in Figure 1 suggest that response and incentive processes were combining algebraically, since during stimulus compounding they enhanced each other when in agreement (both increasing), counteracted each other when in opposition (response increase and reinforcement decrease), and produced intermediate results when only one association was conditioned (response increase) to tone and light. The generality of these combinational dynamics was further explored in a series of stimulus compounding experiments that kept incentive associations to tone and light comparable over groups while manipulating the response-rate change controlled by those stimuli.

#### *Comparable Incentive Associations to Tone and Light over Groups: Manipulation of Between-Component Response-Rate Differences*

A free-operant avoidance (FOA) contingency was in effect during tone and light in three experiments. A response postponed shock by 25 sec, while in the absence of responding shocks were presented every 5 sec.  $\bar{T}+\bar{L}$  was always shock-free. Therefore, the negative reinforcement maintaining responding in tone and in light increased for all groups. The  $\bar{T}+\bar{L}$  contingencies, which varied over groups, were so chosen that tone and light would each maintain (a) a higher response rate than  $\bar{T}+\bar{L}$ , (b) a rate comparable to that in  $\bar{T}+\bar{L}$ , or (c) a lower rate than  $\bar{T}+\bar{L}$ .

(a) Emurian and Weiss (1972) trained rats to respond to postpone shocks in tone and light. No shocks were scheduled in  $\bar{T}+\bar{L}$  and responses were not emitted. In such conditions animals prefer shock-free  $\bar{T}+\bar{L}$  to tone or light (LoLordo, 1969; Verhave, 1962) indicating, according to the top-right cell in

Table 1, that negative incentive ("fear") increased in tone and light. Here, where T+L was again composed of stimuli associated with an increase in both response and incentive, close to 60% of the test responses were emitted to T+L. This is shown as point A in Figure 2.

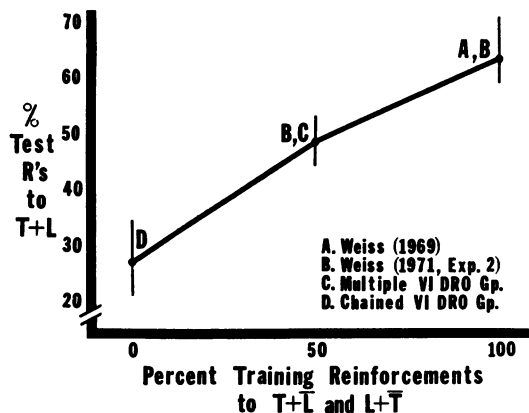


Fig. 1. The percentage of responses emitted to tone-plus-light (T+L) on a stimulus-compounding test, where tone (T+L), light (L+T), and T+L were presented, as a function of the percentage of training session reinforcements received during that half of the session when tone and light were present. Reinforcement rate in tone and in light decreased at the 0% point on the abscissa, remained unchanged at the 50% point, and increased at the 100% point. On all baselines, tone and light each maintained responding while responding ceased in their simultaneous absence, tone-off and light-out ( $\bar{T}+\bar{L}$ ). The vertical lines through each point indicate the range of subject scores represented. (From Weiss and Van Ost, 1974.)

(b) Weiss (1977a) trained rats to postpone shocks by responding in tone and in light while comparable responding was maintained in  $\bar{T}+\bar{L}$  by a VI food schedule. (See Figure 1 and Table 2 in that study.) Nevertheless, the shock schedule produced an incentive increase in tone and in light, since  $\bar{T}+\bar{L}$  was shock free. Under this arrangement, where only incentive factors were operating, T+L controlled 43.5% of the test responses. This value, shown in point B of Figure 2, was 1.5 times the output to tone or light alone, moderate but significant additive summation.

(c) Weiss (1976, Experiment 2) used a schedule similar to that described above in (b), but the VI employed in  $\bar{T}+\bar{L}$  controlled approximately twice the response rate of FOA-correlated tone or light. Here, tone and light each controlled a reduction in response rate,

but, since  $\bar{T}+\bar{L}$  was shock free, they were associated with an increase in avoidance incentive. On a stimulus compounding test,  $T+L$  controlled a response rate comparable to that of tone or light alone (see point C in Figure 2).

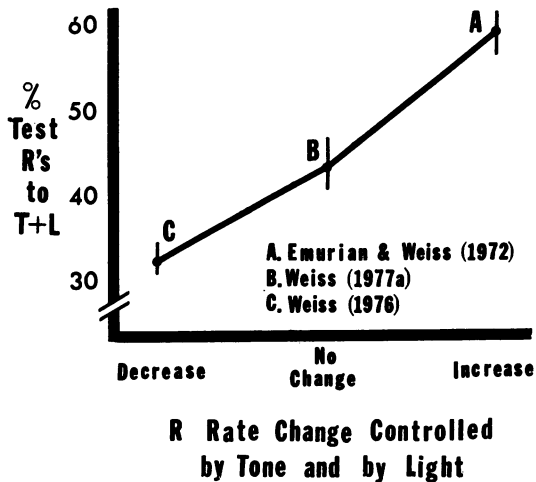


Fig. 2. The percentage of responses emitted to tone-plus-light ( $T+L$ ) on a stimulus-compounding test as a function of tone and light each controlling, relative to rate in the absence of tone and light, response decrease, no change in response, or response increase. In all experiments, responding was maintained in tone and in light by free-operant avoidance, and avoidance incentive increased in these stimuli. The vertical lines intersecting each mean data point present the range of the subject scores represented. [Adapted from Emurian and Weiss (1972) and Weiss (1976, 1977a).]

In summary, whether the independent variable was the incentive factor where responding was maintained to tone and to light by positive reinforcement, as in Figure 1, or the response factor where responding was maintained by negative reinforcement, as in Figure 2, the stimulus compounding tests indicated that response and incentive processes combined algebraically. An integration process of substantial generality has been identified in this systematic series of studies.

## TWO-FACTOR COMBINATIONAL MODEL REPRESENTED IN RESPONSE/INCENTIVE MATRIX

The studies referred to in Figures 1 and 2 included only five response-rate-by-incentive combinations that could be conditioned to

tone and light. However, if *each* of the three types of rate change—*increase*, *no change*, and *decrease*—is combined, respectively, with incentive *increase*, *no change* in incentive, and incentive *decrease*, the nine combinations presented in the  $3 \times 3$  matrix of Table 2 occur.

Within this matrix, the response rate controlled by tone and light, relative to  $\bar{T}+\bar{L}$  rate, is specified by the columns, and the incentive change conditioned to these stimuli, again relative to that in  $\bar{T}+\bar{L}$ , is indicated by the rows. The studies reported in Figure 1 are located in the cells in the left column of Table 2, since tone and light each controlled an increase in response rate. However, when tone and light were simultaneously associated with: (1) an increase in reinforcement after multiple VI Extinction training, the study belongs in the top row of the left column; (2) no change in reinforcement, after multiple VI DRO training, the study belongs in the middle row of the left column; and (3) a decrease in reinforcement, after chained VI DRO training, the study meets the rate and incentive specification of the cell in the bottom row.

The studies in Figure 2 would be located in the appropriate cell in the top row of Table 2, since negative incentive increased in tone and light on all baselines. The particular cell would be determined in addition by whether response rate in tone and light increased (multiple FOA EXT), remained unchanged [multiple FOA VI, Weiss (1977a)], or decreased [multiple FOA VI, Weiss (1976, Experiment 2)].

The combinational dynamics suggested for the five cells just described can be extended to the remaining four cells of Table 2. For example, in the right-column bottom-row cell,  $T+L$  would be composed solely of stimuli associated with a decrease in response and reinforcement, and these associations should optimize the likelihood of  $T+L$  controlling less responding than tone or light alone (subtractive summation). This finding was reported in several experiments where responding was maintained during tone, light, and  $\bar{T}+\bar{L}$  by a VI food-reinforcement schedule, while rate was reduced during both tone and light components by additionally associating these stimuli with signalled shock (Miller, 1969; Weiss and Emurian, 1970) or response

Table 2

Free-operant stimulus compounding experiments classified with respect to response and incentive differences conditioned between baseline schedule components.

Response-rate change Conditioned to Tone and to Light relative to $\bar{T}+\bar{L}$			
Increase		None	Decrease
Incentive change Conditioned to Tone and to Light Relative to $\bar{T}+\bar{L}$	<b>MAXIMUM ADDITIVE SUMMATION</b> VI <sup>a</sup> (Extinction) <sup>b</sup> Long & Allen (1974) Melnick (1972) Meltzer & Freeman (1971) Meltzer & Hamm (1976) Meltzer & Masaki (1972) Tsai & Weiss (1977) Weiss (1964; 1969; 1971, Exp. 2; 1975, Exp. 1) Wolf (1963) VI (VI) Bushnell & Weiss (1978) VI (Chain VI) Meltzer & Niebuhr (1974, Exp. 1) FI (Extinction) Miller (1971) Miller & Ackley (1970) DRL (Extinction) Weiss (1977b) FOA (Extinction) Emurian & Weiss (1972) LoLordo & Hart (1972) Weiss (1976, Exps. 1 & 3) Weiss & Wiltz (1972) FOA + Signalled Sk. (FOA) Riess (1969)	<b>MODERATE ADDITIVE SUMMATION</b>  VI <sup>a</sup> (FOA) <sup>b</sup> Weiss (1977a)   FOA (VI) Weiss (1977a)	<b>MINIMAL OR NO EFFECT</b>  FOA <sup>a</sup> (VI) <sup>b</sup> Weiss (1976, Exp. 2)
	<b>MODERATE ADDITIVE SUMMATION</b> VI <sup>a</sup> (DRO) <sup>b</sup> Weiss (1971, Exp. 2) Weiss & Van Ost (1974)	<b>NO EFFECT</b> VI <sup>a</sup> (VI) <sup>b</sup> Weiss (1977a) FOA (FOA) Weiss (1977a)	<b>MODERATE SUBTRACTIVE SUMMATION</b> Data Not Available
	<b>MINIMAL OR NO EFFECT</b> Chain VI <sup>a</sup> (DRO) <sup>b</sup> Weiss & Van Ost (1974) VI + Punishment (DRO) <sup>c</sup> Wiltz (1972) FOA (Noncontingent Sk.) Weiss (1976, Exp. 3)	<b>MODERATE SUBTRACTIVE SUMMATION</b> Data Not Available	<b>MAXIMUM SUBTRACTIVE SUMMATION</b> Conjunction VI DRL <sup>a</sup> (VI) <sup>b</sup> Weiss (1972) Chain VI (VI) Meltzer & Niebuhr (1974, Exps. 1 & 2) VI + Punishment (VI) Van Houten & Rudolph (1971) Wiltz (1972) VI + Signalled Sk. (VI) Henderson (1975) Miller (1969) Reberg & Black (1969) Van Houten, O'Leary & Weiss (1970) Weiss & Emurian (1970) FOA (FOA) Weiss (1976, Exp. 1) Weiss & Wiltz (1972)

<sup>a</sup>Schedule during tone and during light. VI = variable interval, FI = fixed interval, DRL = differential reinforcement of low rate, FOA = free-operant avoidance.

<sup>b</sup>Schedule effective in tone-off and light-out ( $\bar{T}+\bar{L}$ ). DRO = differential reinforcement of other behavior.

<sup>c</sup>See Footnote 2 (page 368) for a methodological analysis of the studies reported by Wiltz (1972, 1974).

punishment (Van Houten and Rudolph, 1971; Wiltz, 1972). In both cases, where responding was maintained by positive reinforcement in all components,  $T+L$  would be preferred to tone and light, which were also shock associated (Hearst and Sidman, 1961). This preference indicates, according to Table 1, an incentive decrease in tone and light. As predicted by the combinational model,  $T+L$  controlled subtractive summation in all four studies.

Similar subtractive summation was obtained when stimuli controlling FOA were compounded. In these studies, a response in tone or light postponed shock by 25 sec, while a response in  $\bar{T}+\bar{L}$  postponed it only 10 sec (Weiss, 1976, Experiment 1; Weiss and Wiltz, 1972). On this schedule, tone and light each controlled lower response rates than  $\bar{T}+\bar{L}$ , and the former stimuli were preferred to  $\bar{T}+\bar{L}$  (Sidman, 1957; Sidman and Boren, 1957; Weiss, 1976, Experiment 2). This preference indicates that the negative incentive was lower in tone and light than  $\bar{T}+\bar{L}$  (Table 1). Here, where rate and incentive were decreasing in tone and light, subtractive summation was profound, with  $T+L$  controlling roughly one-half the response output of tone or light alone (Weiss, 1976, Experiment 1). This was a unique situation where combining avoidance-associated stimuli yielded less avoidance than presenting those stimuli separately.

When *only* response decrease (right-column middle-row cell) or incentive decrease (middle-column bottom-row cell) has been conditioned to tone and to light, according to the combinational model,  $T+L$  should control more moderate subtractive summation than when these stimuli are associated with a decrease in both, as in the studies just reviewed. Experiments are needed to examine these predictions.

A recent experiment (Weiss, 1977a) con-

tained two control groups meeting the non-differential rate and incentive requirements of the center cell in Table 3. Animals had either the same VI food-reinforcement or FOA schedule operating in tone, light, and  $\bar{T}+\bar{L}$ . In testing, both groups distributed their responses comparably among tone, light, and  $T+L$ , indicating that nonassociative factors made no discernible contribution to the results of stimulus compounding. Although similar findings were reported in those experiments included in the lower-left and upper-right corner cells, these nondifferential results represented active conflicting processes where response and incentive factors operated in opposition.

Predictions from an algebraic combinational model, then, were in good agreement with applicable multimodal free-operant stimulus-compounding studies performed to date. Only two of the nine cells remain unexplored. More parametric exploration is necessary to determine (1) how the three ordered categories on the response and incentive axes might be scaled intervally, and (2) the characteristics of a scale that could be applied to both factors. Within limits, when single stimuli were associated with substantive increases in response and incentive, greater summation would be anticipated during compounding than when the single stimuli were each associated with small increases. In fact, a schedule that produces a large rate increase but no incentive change could generate greater summation than a schedule that produces only a moderate increase in both factors (see Bushnell and Weiss, 1978). This means that, currently, comparisons between cells are parametrically meaningful only when relevant variables other than the manipulated factor are comparable. This comparability includes methods of training and testing (see Weiss, 1972, p. 205).

<sup>2</sup>Wiltz (1974) reported additive summation during stimulus compounding after training on a baseline similar to that used by Wiltz (1972), where summation was not obtained. This could be due in part to the different conditioning histories in  $\bar{T}+\bar{L}$  between experiments. However, these experiments must be interpreted cautiously with respect to the present analysis. Well over one-third of the response-produced shocks in tone as well as in light were presented simultaneously with food, making it likely that the mild shocks acquired some positive properties through

their food-signalling function (see Azrin and Holz, 1966; Freeburne and Taylor, 1952; Logan and Wagner, 1965). [This shock-food correlation is revealed by examination of the training cumulative records presented by Wiltz (1972) when the reinforcement presentations indicated by slash marks of the response pen are lined up with response-produced shocks recorded by the event pen. Unfortunately, shock data were excluded from the records in Wiltz (1974)]. These experiments should be replicated with more care taken to keep shock and food presentations independent.



### EXTENSION OF MODEL TO BEHAVIORAL CONTROL ON TRAINING BASELINES

The two-factor model has predicted the results of stimulus compounding. However, the studies described in Figure 1 do present a problem. Comparable baseline behaviors were maintained in tone and in light by different combinations of response and incentive factors. (See Section A of Table 3.) The composite-stimulus control analysis (Weiss, 1969, 1972) suggests a resolution consistent with the combinational principles employed to explain the compounding test outcomes.

#### Composite-Stimulus Control Analysis

According to this formulation, the  $S^D$ s comprising the complex baselines are viewed in terms of their composite elements. Thus, tone would be defined as tone and light-out ( $T+\bar{L}$ ), light as light and tone-off ( $L+\bar{T}$ ), and the simultaneous absence of tone and light as tone-off and light-out ( $\bar{T}+\bar{L}$ ). Within this framework, the "on" as well as the "off" elements are assumed to control behavior, with the organism sampling each. As a consequence of this sampling, a "mixture" of the habits conditioned to each of the elements would result (Weiss, 1972, p. 194). On the response side, this mix should yield comparable outcomes in  $T+\bar{L}$  and  $L+\bar{T}$  on each baseline where an element discriminative for response increase ( $\uparrow$ ), T or L respectively, and an element discriminative for response de-

crease ( $\downarrow$ ),  $\bar{L}$  or  $\bar{T}$  respectively, would be sampled in "tone" and in "light".

The present formulation expands this analysis by considering the reinforcement (incentive) associations in addition to the response-rate change. Section B of Table 3 schematically shows that on both the multiple VI EXT and chained VI DRO schedules, an element associated with reinforcement increase and another with reinforcement decrease are sampled during  $T+\bar{L}$  and  $L+\bar{T}$ . However, the "mix" of high and low reinforcement associated elements should yield comparable resultants, even though these composite-element reinforcement associations are reversed over schedules. Furthermore, it seems reasonable to assume that the incentive "level" resulting to the conflicting  $\uparrow$  and  $\downarrow$  associations could be comparable to that produced when similar ( $=$ ) rates of reinforcement occur in T, L,  $\bar{T}$ , and  $\bar{L}$ , as on the multiple VI DRO schedule.

If we assume (1) composite-element sampling, (2) a "mix", on the response and incentive dimensions, of the properties ( $\uparrow$ ,  $\downarrow$  or  $=$ ) acquired by each element, and (3) an algebraic combination of the results of each "mix", equalities are generated to  $T+\bar{L}$  and  $L+\bar{T}$  over the three schedules. (See Section B of Table 3.) These equalities were achieved through a *post hoc* application of the assumptions. They could be tested predictively through a unique recombination of the elements with only those properties postulated to the elements present in the recombination considered.

Table 3

Direction of change in response rate and incentive in tone ( $T+\bar{L}$ ), light ( $L+\bar{T}$ ), and tone-plus-light ( $T+L$ ).

		Schedule		
		Multiple VI Extinction	Multiple VI DRO	Chained VI DRO
A. Treating Tone and Light as Unitary Stimuli	Factor	Tone and Light	Tone and Light	Tone and Light
	Response Incentive	$\uparrow$ $\uparrow$	$\uparrow$ $=$	$\uparrow$ $\downarrow$
B. Composite-Stimulus Analysis	Factor	$T+\bar{L}$ and $L+\bar{T}$	$T+\bar{L}$ and $L+\bar{T}$	$T+\bar{L}$ and $L+\bar{T}$
	Response Incentive	$\uparrow \downarrow$ $\uparrow \downarrow$	$\uparrow \downarrow$ $=$	$\uparrow \downarrow$ $\uparrow \downarrow$
C. Recombination of Composite Elements during Compounding	Factor	$T+L$	$T+L$	$T+L$
	Response Incentive	$\uparrow \uparrow$ $\uparrow \uparrow$	$\uparrow \uparrow$ $=$	$\uparrow \uparrow$ $\downarrow \downarrow$

### *Predictions of Behavior to Recombined Elements*

The composite elements are recombined on a stimulus compounding test where the tone-plus-light (T+L) composite is presented for the first time. In T+L, the response and incentive properties conditioned to  $\bar{T}$  and  $\bar{L}$  are not contributing to the "mix", as they are in  $T+\bar{L}$  and  $L+\bar{T}$  composites, since only T and L elements can be sampled. Section C of Table 3 presents, for each schedule, the response and incentive properties postulated to the stimulus elements comprising T+L. Within this schematic presentation, an application of the attentional and combinational assumptions presented above produces several clear, ordinal predictions:

- (1) After the multiple VI EXT training, with four  $\uparrow$  associations T+L should control more responding than  $T+\bar{L}$  or  $L+\bar{T}$  that each contain two  $\uparrow$  and two  $\downarrow$  associations.
- (2) After the multiple VI DRO training, with two  $\uparrow$  associations T+L should control more responding than  $T+\bar{L}$  or  $L+\bar{T}$  that each contain one  $\uparrow$  and one  $\downarrow$  association.
- (3) With four  $\uparrow$  associations, T+L in (1) should control greater summation than T+L in (2) that contains only two  $\uparrow$  associations.
- (4) After the chained VI DRO training T+L,  $T+\bar{L}$  and  $L+\bar{T}$  should control roughly comparable response rates since each composite contains two  $\uparrow$  and two  $\downarrow$  associations.

The results presented in Figure 1 clearly support these predictions. The two-factor combinational model of composite stimulus control appears to explain both the training and test outcomes in tone, light, and T+L on these baselines. Moreover, a similar analysis can be successfully applied to the experiments presented in Figure 2.

### APPLICATION OF COMBINATIONAL MODEL TO STIMULUS-GENERALIZATION PEAK-SHIFT

A translation of the stimulus-compounding design that permits functional comparison

with stimulus generalization peak-shift experiments is made possible if the tone and light are treated as composite stimuli, taking into account both the "on" and the "off" states of each. Then, one can generate a "composite continuum" with respect to the number of elements "on". In this instance, the continuum would extend from the all-off extreme [tone-off and light-out ( $\bar{T}+\bar{L}$ )], through the one-stimulus-on conditions [tone ( $T+\bar{L}$ ) and light ( $L+\bar{T}$ )], to the all-on extreme [tone-plus-light (T+L)]. An appreciation of the possible comparability of component and wavelength situations was also expressed by Guttman (1965), who speculated that "... such [wavelength] stimulation produces an effect with several components, . . . , and it may well turn out that the results obtained with wavelength will be more readily generalizable to multidimensional stimulus situations than to unidimensional cases" (p. 271). The combinational model formulated from compounding research attempts generalization of principles in a direction opposite to that anticipated by Guttman.

After training, where responding is correlated with extinction in  $\bar{T}+\bar{L}$  ( $S^A$ ) and maintained with reinforcement in  $T+\bar{L}$  and  $L+\bar{T}$ , subjects show additive summation to T+L (Wolf, 1963; Weiss, 1964). This response-enhancement effect was likened to peak shift because, on the composite continuum, T+L is further removed from  $\bar{T}+\bar{L}$  ( $S^A$ ) than either  $T+\bar{L}$  or  $L+\bar{T}$   $S^D$ s. In positive peak shift, maximum responding is controlled by a stimulus removed from  $S^D$  in a direction away from  $S^A$  (cf. Hanson, 1959). Figure 3 is a schematic description of this relationship in summation and peak-shift studies. Similarly, subtractive summation, where T+L controls a lower rate than  $T+\bar{L}$  or  $L+\bar{T}$  after training in which the high-rate stimulus is  $\bar{T}+\bar{L}$ , seems analogous to negative peak shift. In negative peak shift, the minimum rate on a generalization test is controlled by a stimulus removed from the lowest-rate training stimulus in a direction away from the high-rate training stimulus.

### *Functional Similarities between Peak Shift and Summation*

Generalization studies reporting peak shift and the stimulus-compounding studies reporting summation involve several functional similarities (Weiss, 1969, 1971, 1972).

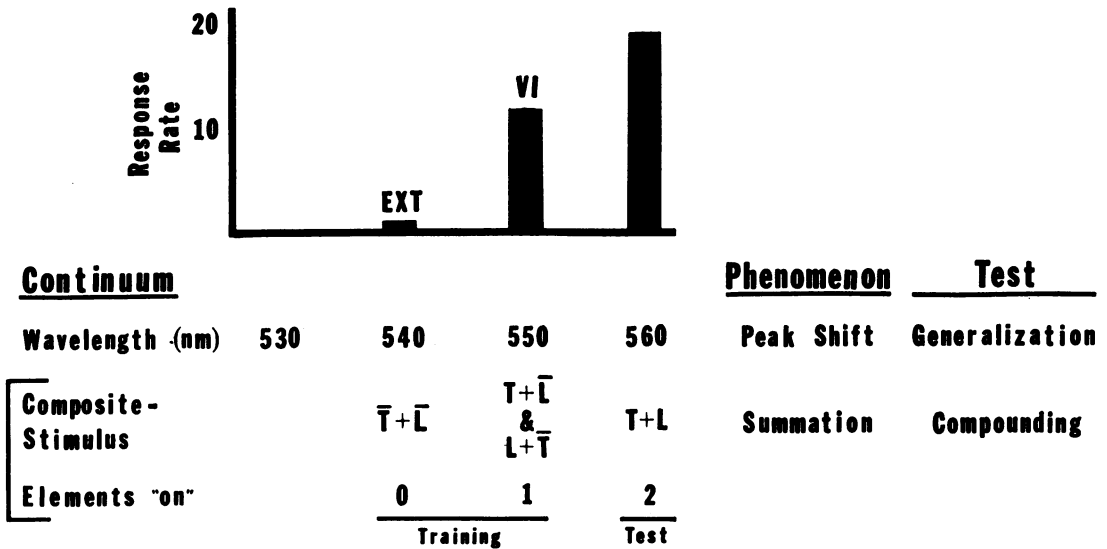


Fig. 3. Schematic representation of experimental paradigms that produce peak shift in generalization and summation in stimulus compounding. This representation is arranged so as to focus on the similarities between the two situations when the training and test conditions of the stimulus-compounding paradigm are organized along a composite-stimulus dimension with respect to the number of elements "on".

(1) *Intradimensional discrimination training* is necessary for both peak shift and summation. Rats do not show summation to  $T+L$  when they experience only tone and light in training (Weiss, 1971, Experiment 1), just as pigeons do not show peak shift if they experience only one wavelength (Guttman and Kalish, 1956; Hanson, 1959). Furthermore, nondifferential training with tone, light, and  $\bar{T} + \bar{L}$  is inadequate for summation to  $T+L$  (Weiss, 1977a), just as nondifferential training between  $S_1$  (540 nm) and  $S_2$  (550 nm) does not produce peak shift (Thomas and Williams, 1963).

(2) *The interchangeability of function between  $S^D$  and  $S^A$  values* along the unitary dimensions employed in peak-shift studies also occurs along the composite-continuum postulated to underlie summation. Additive summation occurred to  $\bar{T} + \bar{L}$  when responding was maintained with food to  $T + \bar{L}$  and  $L + \bar{T}$  if  $T+L$  was  $S^A$  (Weiss, 1969). Similarly,  $\bar{T} + \bar{L}$  could control subtractive summation when the highest rate in training was maintained by  $T+L$  (Weiss and Emurian, 1970). (Also see Tsai and Weiss, 1977.)

(3) Finally, *reinforcement differences between multiple-schedule components* ( $S_1$  and  $S_2$ ) influence peak-shift as well as magnitude of summation. This function has been described for stimulus compounding in Figure

1. A parallel series of generalization studies has been performed by Yarczower, Dickson, and Gollub (1966) and Yarczower, Gollub, and Dickson (1968). For three groups of pigeons,  $S_1$  controlled a higher response rate than  $S_2$ . However, one group received all reinforcements in  $S_1$  (multiple VI 30-sec EXT), another had comparable reinforcement rates in  $S_1$  and  $S_2$  (multiple VI 60-sec DRO 50-sec), and the third received reinforcements three times as often in  $S_2$  as  $S_1$  [multiple (tand VI 30-sec DRL 4-sec) DRO 10-sec]. Unfortunately, individual data are unavailable for group one, where  $S_1$  was associated with an increase in response and reinforcement rate. However, the mean gradient clearly showed a positive peak shift, and since these are the prototypic training conditions under which the phenomenon is conventionally reported, it seems safe to assume that the mean represents individual gradients. When  $S_1$  controlled just an increase in response and signalled no change in reinforcement, three-quarters of the birds shifted. Finally, when  $S_1$  was associated with *conflicting* rate increase and reinforcement decrease, only one-quarter of the pigeons showed peak shift. The apparent similarity of functions revealed in those studies and that presented in Figure 1 suggests that presently, likelihood of peak shift might be viewed as analogous to magnitude of summation

when applying the combinational model to the peak-shift literature. In the future, this rather gross measure might be further refined by also considering the areas of the gradient on either side of  $S_1$ .

The functional similarities outlined in the above comparison indicate that the two-factor combinational model induced from research in stimulus compounding might help in identifying some of the variables operating to produce peak shift. In applying the model to stimulus generalization, the axes of Table 2 are modified such that columns refer to " $S_1$  response rate relative to  $S_2$ " and rows to " $S_1$  incentive relative to  $S_2$ ". This is shown in Table 4.

Peak shift is a complex phenomenon that can be "... affected by the stimulus dimension, the positive-negative stimulus separation, the training procedure and the testing procedure" (Purtle, 1973, p. 408). [See Rilling (1977) for a recent comprehensive and insightful evaluation.] Thus, a clear indication of the influence of the two factors isolated in Table 4 requires that other variables influencing the phenomenon be kept comparable as rate and/or incentive differences between  $S_1$  and  $S_2$  are parametrically investigated. Unfortunately, this has seldom been the case.

#### Peak-Shift Experiments

According to the combinational principles, the between-schedule component response and reinforcement relations that maximize summation should also maximize the likelihood of peak shift. This would occur when  $S_1$  is discriminative for a response increase and also signals an increased probability of reinforcement (or a more valued condition). These conditions, represented in the left-column top-row cell of Table 4, characterize the great majority of experiments reporting peak shift: (1) Hanson's (1959) original demonstration of peak shift, where  $S_2$  signalled extinction while  $S_1$  was associated with VI food reinforcement; (2) Guttman's (1959) condition, where  $S_1$  was associated with VI 1-min and  $S_2$  with VI 5-min reinforcement schedules; and (3) those experiments reporting peak shift where reinforcement rates were comparable in  $S_1$  and  $S_2$ , but response rate was reduced in  $S_2$  by manipulations such as (a) punishment (Terrace, 1968), (b) delay of reinforcement (Wilkie, 1972), or (c) reduction in reinforcement

duration (Mariner and Thomas, 1969). For each instance, other research has indicated that  $S_1$  would be preferred to  $S_2$  (Brownstein, 1971; Catania, 1963; Chung and Herrnstein, 1967; De Villiers and Millenson, 1972; Hearst and Sidman, 1961; Herrnstein, 1964b; Holz *et al.*, 1963).

In the majority of studies reporting positive peak shift, responding was maintained in  $S_1$  by positive reinforcement, while responding in  $S_2$  was nonreinforced ( $S^\Delta$ ). Studies employing wavelength, frequency, intensity, flicker, line-tilt, or click-rate dimensions in standard successive discrimination training were surveyed that established clear  $S^D/S^\Delta$  response differences and used conventional (Hanson, 1959) testing. Peak shift was reported in at least 75% of the subjects tested in approximately 80% of the 65 total groups contained in the studies cited in Footnote 3.

Negative peak shift means that the *minimum* response rate during a generalization test is controlled not by  $S_1$ , the stimulus maintaining the lowest response in training, but a stimulus removed from  $S_1$  in a direction away from  $S_2$ , the stimulus controlling the highest response rate in training. Those response and reinforcement conditions that maximize subtractive summation should be optimal for producing negative peak shift. These conditions are represented in the right-column bottom-row cell of Table 4, where  $S_1$  would be discriminative for a response reduction, as well as a decrease in incentive, relative to  $S_2$ . These conditions have indeed shown negative peak shift (*e.g.*, Guttman,

<sup>3</sup>The following studies all employed successive discrimination training where  $S_1$  and  $S_2$  alternated [ $S_1$  was associated with a VI food reinforcement schedule and  $S_2$  with nonreinforcement (Extinction)]: Ames and Yarczower (1965), Bloomfield (1967), Bushnell (1978), Doll and Thomas (1967), Dukhayil and Lyons (1973), Dysart *et al.* (1974), Ellis (1970), Ernst, Engberg, and Thomas (1971), Gerry (1971), Grusec (1968)\*, Hearst (1968, 1971)\*, Heinemann and Chase (1970), Honig (1962), Huff, Sherman, and Cohen (1975), Pierrel and Sherman (1960, 1962), Rudolph and Honig (1972), Rudolph, Van Houten, and Maddox (1971), Sloane (1964), Stevenson (1966, Experiment 1), Terrace (1964a, 1966, Experiment 2, 1975), Thomas (1962)\*, Thomas and Burr (1969), Thomas and Lyons (1968), Thomas and Setzer (1972), Thomas and Williams (1963), Thomas, Ost, and Thomas (1960), Wildeman and Holland (1973), Williams (1973), Yarczower, Dickson, and Gollub (1966), and Yarczower, Gollub, and Dickson (1969). (\* = Peak shift was not obtained.)

**Table 4**  
**Application of Two-Factor Model to Generalization Peak-Shift**

Response-Rate Change Conditioned to S <sub>1</sub> Relative to S <sub>2</sub>				
		Increase	None	Decrease
Incentive Change Conditioned to S <sub>1</sub> Relative to S <sub>2</sub>	Increase	<p><b>MAXIMUM LIKELIHOOD OF POSITIVE PEAK-SHIFT</b></p> <p>VI<sup>a</sup> (Extinction)<sup>b</sup> VI 12" (VI 24" or 60")  Hanson (1959) Wheatley &amp; Thomas (1974)  Plus 30 studies given in Footnote 3. VI 30"-DRL 4" (VI 4'-DRL 8")  Yarczower et al. Yarczower et al. (1966)<sup>c</sup>  VI (Extinction + Sk.) VI (Chain VI)  Gerry (1971) Frieman &amp; Thomas (1970)  Grusec (1968)  VI (VI + Punishment) VI 1'-2" sig. reinf.  Terrace (1968, Exp. 2) (VI 1'-6" sig. reinf.)  Mariner &amp; Thomas (1969)  VI (VI delayed reinf.) Wilkie (1972) VI 40"  VI 1' (VI 5' or VI 2') (Partially extinguished  Guttman (1959) VI 40")  Terrace (1968, Exp. 1)<sup>d</sup> Guttman (1965)  FOA (Extinction)  Wheatley &amp; Thomas Klein &amp; Rilling (1974)<sup>c</sup>  Dysart et al. (1974)<sup>c</sup> Bushnell (1978)</p>	<p><b>MODERATE LIKELIHOOD OF POSITIVE PEAK-SHIFT</b></p> <p>VI 2.5"<sup>a</sup> (VI 5")<sup>b</sup>  Wheatley &amp; Thomas (1974)<sup>c</sup>  VI 30"-DRL 4" (VI 3'-DRL 2")  Yarczower et al. (1966)<sup>c</sup>  VI 1'2" unsig. reinf. or VI 1'6" unsig. reinf.  (VI 1'6" unsig. reinf. or VI 1'10" unsig. reinf.)  Dickson &amp; Thomas (1963)<sup>c</sup>  Mariner &amp; Thomas (1969)<sup>c</sup></p>	<p><b>MINIMAL LIKELIHOOD OF PEAK-SHIFT</b></p> <p>No Data Available</p>
	None	<p><b>MODERATE LIKELIHOOD OF POSITIVE PEAK-SHIFT</b></p> <p>VI 1"<sup>a</sup> (DRL 6")<sup>b</sup>  Terrace (1968, Exp. 3)  VI 1' (DRO 50")  Yarczower et al. (1968)  VI 1' (VT 1')  Huff, Sherman &amp; Cohen (1975)</p>	<p><b>MINIMAL LIKELIHOOD OF PEAK-SHIFT</b></p> <p>VI 1"<sup>a</sup> (VI 1')<sup>b</sup>  Dickson &amp; Thomas (1963)<sup>c</sup>  Dysart et al. (1974)<sup>c</sup>  Thomas &amp; Williams (1963)<sup>c</sup>  VI 1' (DRL 6")  Terrace (1968, Exp. 3)<sup>c</sup></p>	<p><b>MODERATE LIKELIHOOD OF NEGATIVE PEAK-SHIFT</b></p> <p>No Data Available</p>
	Decrease	<p><b>MINIMAL LIKELIHOOD OF PEAK-SHIFT</b></p> <p>VI 30"-DRL 4"<sup>a</sup> (DRO 10")<sup>b</sup>  Yarczower et al. (1968)<sup>c</sup></p>	<p><b>MODERATE LIKELIHOOD OF NEGATIVE PEAK-SHIFT</b></p> <p>No Data Available</p>	<p><b>MAXIMUM LIKELIHOOD OF NEGATIVE PEAK-SHIFT</b></p> <p>VI 2' + sig. sk.<sup>a</sup>  (VI 2' + sig. nonsk.)<sup>b</sup>  Hendry, Switalski &amp; Yarczower (1969)  Partially extinguished VI 40" (VI 40")  Guttman (1965)  Extinction (VI 20")  Heinemann &amp; Chase (1970)</p>

\*Schedule effective during S<sub>1</sub>. VI = variable interval, DRL = differential reinforcement of low rate, VI-DRL = tandem schedule in which reinforcements are delivered according to the VI only if the time between responses meets or exceeds the DRL value, FOA = free-operant avoidance.

<sup>b</sup>Schedule effective during S<sub>2</sub>. DRO = differential reinforcement of other behavior, VT = response-independent variable time.

<sup>c</sup>Peak shift was not obtained.

<sup>d</sup>Training sequence was a factor in results. See section on "Inhibition and Stimulus Control".

1965; Hendry, Switalski, and Yarczower, 1969). Guttman (1965) surmounted the "floor effect" problem by correlating extinction with the low-rate stimulus only until it controlled roughly 25% of the rate of the still reinforced VI 40-sec stimulus. He reported both a positive and a negative peak shift in the same study, one of the few investigators to do so. By changing the stimulus used as a reference, that study can also be placed in the left-column top-row cell of Table 4.

Although the conditions described above are optimal for negative peak shift, according to the two-factor model there should be a moderate likelihood of negative peak shift if either response rate or reinforcement is reduced in  $S_1$ . Unfortunately, no relevant data are available. However, positive peak shift has been reported in studies that are the mirror image of the rate-reduction experiment just referred to. Reinforcement rates in  $S_1$  and  $S_2$  were comparable, while  $S_1$  was discriminative for response increase (e.g., Huff, Sherman, and Cohn, 1975; Terrace, 1968; Yarczower, Gollub, and Dickson, 1968). When Huff *et al.* employed a multiple VI 60-sec VT 60-sec schedule, three of six rats showed positive peak shift. Their comparison multiple VI 60-sec Extinction group is especially relevant to the current analysis. Here, where response and reinforcement increased in  $S_1$ , the probability of peak shift doubled.

The combinational model predicts minimal likelihood of peak shift when  $S_1$  is discriminative for response increase but signals a decrease in reinforcement (see left-column bottom-row cell in Table 4). The only study meeting those requirements supports this prediction (Yarczower *et al.*, 1968). Certainly, further investigation of these conflicting factor conditions are sorely needed for confirmation, as are studies meeting the requirements of the right-column top-row cell—response decrease and reinforcement increase in  $S_1$ .

Wheatley and Thomas (1974) and Yarczower *et al.* (1966) performed generalization studies where baseline responding was comparable in  $S_1$  and  $S_2$  while reinforcement rate increased in  $S_1$ . These conditions should create a moderate likelihood of positive peak shift (see middle-column top-row cell in Table 4). Neither experiment reported peak shift. Unfortunately, with nondifferential responding in these pigeons, there is no way

of knowing if they were under any kind of exteroceptive stimulus control. Similar experiments should be performed with independent preference tests, as in the nondifferential response-rate studies isolating the influence of stimulus-reinforcer associations in stimulus compounding (Weiss, 1977a). The same interpretive problem applies to the two studies in this cell that manipulated unsignalled reinforcement duration between components. Concurrent choice experiments have shown that response rate is related to relative magnitude of reinforcement (Catania, 1963; de Villiers and Millenson, 1972). Thus, the comparable response rates in  $S_1$  and  $S_2$  reported by Dickson and Thomas (1963) and Mariner and Thomas (1969) probably indicate that duration differences were not perceived. Adding an identifiable signal to these different reinforcement durations did result in baseline rate differences and peak shift (Mariner and Thomas, 1969).

Dysart, Marx, McLean, and Nelson (1974) reported a 0.972 correlation between relative response and relative reinforcement over five multiple schedules ranging from VI 60-sec Extinction to VI 60-sec VI 300-sec. This naturally occurring covariation indicates the technical difficulty of having  $S_1$  and  $S_2$  control comparable response rates and patterning when they are associated with differential reinforcement. In the author's experience, high-rate requirements (ratios, limited holds, *etc.*) in the lower reinforcement periods produce differential response patterns over components. On the other hand, reducing responding by low-rate requirements can impede exteroceptive stimulus control (Hearst, Koresko, and Poppen, 1963) and might even preclude rate increases in testing, since these would have reduced reinforcement in training.

Weiss (1977a) developed a schedule that surmounted these problems. Although comparable responding was maintained in tone, light, and  $\bar{T}+\bar{L}$ , different classes of reinforcer maintained responding in tone and in light than in  $\bar{T}+\bar{L}$ . This defined an incentive increase in tone and light relative to  $\bar{T}+\bar{L}$ . Here,  $T+L$  controlled additive summation whether food or avoidance schedules were operating in tone and light, showing that differential responding was not necessary for summation. Extrapolating from these results to the peak shift, if comparable responding was main-

tained to  $S_1$  and  $S_2$  by positive and negative reinforcement, respectively, bimodal positive peak shift is predicted.

*Summary.* Application of a two-factor combinational model of stimulus control to generalization peak-shift data has been encouraging, although certainly further investigation is necessary. Those multiple-schedule conditioned response and incentive associations that maximize additive summation do likewise for positive peak shift, while those that maximize subtractive summation are also optimal for negative peak shift. Furthermore, where these associations conflict, one increasing and the other decreasing, summative as well as peak-shift effects appear to be minimized or eliminated.

The processes identified here are general, applying over different organisms, response systems, and stimulus dimensions. Most of the studies in Table 2 employed rats in a bar-pressing paradigm. However, pigeons pecking keys have also shown additive and subtractive summation (Long and Allen, 1974; Meltzer and Hamm, 1976). Likewise, though a vast majority of the generalization studies in Table 4 employed pigeons pecking illuminated discs, peak shift has been reported with rats pressing levers (Huff *et al.*, 1975; Pierrel and Sherman, 1960, 1962), pigeons hopping on treadles (Bushnell, 1978), and humans operating telegraph keys (Doll and Thomas, 1967). Although all these studies employed positive reinforcement, comparable findings have been reported with negative reinforcement. Additive and subtractive summation has been obtained when rats' lever pressing was maintained by avoidance (Emurian and Weiss, 1972; Weiss, 1976, Experiment 1) and peak shift has recently been reported with pigeons avoiding shock with treadle pressing (Bushnell, 1978). Thus, the characteristics of the operant, its resemblance to the consummatory response elicited by the reinforcer, and whether or not the  $S^D$  is "tracked" (Hearst and Jenkins, 1974) by the response do not seem to present limitations on the operation of the processes.

#### INHIBITION AND STIMULUS CONTROL

There has been much speculation that positive peak shift is dependent on  $S_2$  ac-

quiring inhibitory control relative to  $S_1$ , a position having its roots in Spence's (1937) theoretical treatment of transposition. He postulated that transposition resulted from the summation of separate stimulus generalization gradients of excitation and inhibition. While an excitatory gradient is defined by its convex shape, a concave gradient is used to infer inhibitory control (Jenkins, 1965). In most instances,  $S_2$  acquires inhibitory control through correlation with reduced rates of reinforcement, or a less preferred condition. This reinforcement manipulation is almost always accompanied by reduced responding in  $S_2$ . On what, then, is the inhibitory gradient dependent—a reduction in reinforcement, response, or both?

A reduction in response rate to  $S_2$  alone is sufficient for generating an inhibitory gradient. These generalization experiments employed interdimensional discrimination training paradigms. Responding was maintained in the presence of a colored key ( $S_1$ ) by a VI food reinforcement schedule, while the schedule operating when a vertical line ( $S_2$ ) was superimposed on the colored key maintained reinforcement rate while reducing response rate. Subsequent line-orientation generalization tests showed concave gradients around  $S_2$  when the rate reduction in this condition was produced by a low-rate schedule (Weisman, 1969), an other-behavior schedule (Weisman, 1970), a response-independent variable-time schedule (Weisman and Ramsden, 1973), or delay of reinforcement (Richards, 1973). Weisman's (1969) research also indicated that those conditions of discrimination training unlikely to produce peak shift also failed to yield inhibitory gradients around the low-rate stimulus. However, those training conditions producing peak shift in the intradimensional situation also generate inhibitory gradients after interdimensional training (Rilling, 1977).

This relationship between inhibitory stimulus control and the peak shift suggests that the two-factor model presented here applies when response-rate and/or incentive differences conditioned between schedule components produce inhibitory gradients along the low-rate and/or low-incentive dimensions. Further, if these two factors combine algebraically, either by itself should be sufficient for an attenuated inhibitory gradient. On the

other hand, associating a stimulus with reduced responding and increased reinforcement, or *vice versa*, should generate a flat gradient.

Research has not yet determined whether a reduction in reinforcement is alone sufficient to generate an inhibitory gradient or whether conflicting rate and incentive would produce an essentially flat gradient. However, the failure of Yarczower *et al.* (1968) to report peak shift when their low-rate stimulus was simultaneously associated with an increase in reinforcement and reduced responding supports the combinational position.

After intradimensional "errorless" discrimination training,  $S_1$  is associated with both a higher response and reinforcement rate than  $S_2$ . Nevertheless, peak shift is not obtained (Grusec, 1978; Terrace, 1964). Nor is an inhibitory gradient generated around  $S_2$  after "errorless" discrimination training (Terrace, 1966b). Therefore, if inhibitory control is a necessary byproduct of discrimination learning for the response and incentive factors to operate in the combinational fashion suggested by Tables 2 and 4, peak shift would not be anticipated after "errorless" learning. On the other hand, inhibitory gradients would be anticipated to the low-rate and/or low-reinforcement conditions found in those baselines producing additive summation or positive peak shift. For those schedules where gradient data are available, examination of Tables 2 and 4 shows that this is the case. However, such data are lacking for schedules contained in the middle-column top-row cell of those tables. It should also be noted that "errorless" learning has never been reported in the training baseline phase of any stimulus-compounding experiment.

### CONCLUSION

Given the assumption that inhibitory control, as revealed by concave gradients, is necessary for summation and peak shift, reinforcement (incentive) and response reduction appear as separable contributions to inhibition—a position also suggested by Gutman (1977) and Rilling (1977). Independent manipulation of each factor produced roughly comparable summation during stimulus compounding, with the results amplified when both factors were operating in concert. The

qualitatively similar results found when response, incentive, or both factors are positively correlated in the operant situation can be attributed to the algebraic combinational mechanism. The frequency of this response/incentive covariation is clearly apparent in the left-column top-row and right-column bottom-row cells of both Tables 2 and 4. Coupling this experimental covariation with their algebraic combination helps explain why a model concerned with differential response rates (Weiss, 1972) and another exclusively involved with classical learning (Rescorla and Wagner, 1972) predict similar outcomes for stimulus compounding studies in these cells. It also suggests why the elegant neo-Spencian model of generalization and discrimination developed by Blough (1975) fits the available data so well. Blough "... assumes that trials with [stimuli in a set] have consequences (food reinforcement for example) that modify the probability of response in the presence of the stimuli according to a linear equation" (p. 4). Thus, his model does not concern itself with the remaining cells in Table 4, where response and reinforcement are not positively related. However, it is the control represented by these cells that permits the response and incentive factors operating in the instrumental situation to be isolated and appreciated.

Many learning theorists have taken the position that a discriminative stimulus in the instrumental situation can acquire two independent functions—one controlling motivation through the stimulus-reinforcer relation and the other controlling response discriminations through the response-reinforcer relation (*e.g.*, Amsel, 1972; Konorski, 1967; Overmier and Schwarzkopf, 1974; Trapold and Overmier, 1972). However, while this formulation professes that both functions are acquired within the instrumental situation, its implications have been tested successfully primarily through multiphase transfer-of-control experiments where response and incentive associations are acquired separately, and sequentially, in different learning paradigms (*e.g.*, Bull and Overmier, 1968; Rescorla and LoLordo, 1965; Weisman and Litner, 1969). By breaking the usual covariation in response and reinforcement, the research program described earlier (see Figures 1 and 2) directly investigated for the first time



both discriminated response and incentive processes as they are acquired exclusively through the response-reinforcer contingencies operating on complex baselines.

This stimulus compounding research revealed that response and incentive processes enhanced each other when in agreement, counteracted each other when in opposition, and produced results intermediate to these extremes when only one factor was operating. This algebraic combination principle was profitably applied in determining the possible contribution of response and incentive processes to the peak-shift effect in generalization experiments. However, it is clear that much research remains to be done in testing predictions for the many response/incentive combinations in Table 4 for which data is inadequate, insufficient, or unavailable. Of particular concern are those conditions where these processes are conflicting and where only the incentive factor is differentially operating. In this regard, the algebraic combination mechanism has been more comprehensively explored in the stimulus-compounding situation.

The stimulus-compounding and generalization peak-shift research reported over the last two decades has been organized within a two-factor framework, extending this traditional approach to learning to active research areas heretofore not systematically considered in these terms. The fact that so much research employing complex baselines from many different laboratories fits within this organizational matrix suggests that the variables isolated are powerful factors in determining stimulus control, and that the combinational principle postulated has broad application.

## REFERENCES

- Ames, L. L. and Yarczower, M. Some effects of wavelength discrimination on stimulus generalization in the goldfish. *Psychonomic Science*, 1965, 3, 311-312.
- Amsel, A. Behavioral habituation, counterconditioning, and a general theory of persistence. In A. H. Black and W. F. Prokasy (Eds), *Classical conditioning II. current theory and research*. New York: Appleton-Century-Crofts, 1972. Pp. 409-426.
- Autor, S. M. The strength of conditioned reinforcers as a function of frequency and probability of reinforcement. In D. P. Hendry (Ed), *Conditioned reinforcement*. Homewood, Illinois: Dorsey Press, 1969. Pp. 127-162.
- Azrin, N. H. and Holz, W. C. Punishment. In W. K. Honig (Ed), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 380-447.
- Badia, P. and Culbertson, S. The relative aversiveness of signalled versus unsignalled escapable and inescapable shock. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 463-471.
- Bloomfield, T. M. A peak shift in the line tilt continuum. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 361-365.
- Blough, D. S. Steady state data and a quantitative model of operant generalization and discrimination. *Journal of Experimental Psychology: Animal Behavior Processes*, 1975, 104, 3-21.
- Brown, J. S. *The motivation of behavior*. New York: McGraw-Hill, 1961.
- Brownstein, A. J. Concurrent schedules of response-independent reinforcement: duration of a reinforcing stimulus. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 211-214.
- Bull, J. A. and Overmier, J. B. Additive and subtractive properties of excitation and inhibition. *Journal of Comparative and Physiological Psychology*, 1968, 66, 511-514.
- Bushnell, M. C. *An investigation of behavioral contrast and peak shift for autoshaped and operant behavior*. Unpublished doctoral dissertation, The American University, 1978.
- Bushnell, M. C. and Weiss, S. J. A microanalysis of variable-interval responding during stimulus compounding. *Animal Learning and Behavior*, 1978, 6, 66-71.
- Catania, A. C. Concurrent performances: a baseline for the study of reinforcement magnitude. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 299-300.
- Chung, S. H. and Herrnstein, R. J. Choice and delay of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 67-74.
- DeVilliers, P. A. and Millenson, J. R. Concurrent performances: a baseline for the study of conditioned anxiety. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 287-294.
- Dickson, J. F. and Thomas, D. R. Operant discrimination learning and stimulus generalization as a function of reward exposure. *Journal of Comparative and Physiological Psychology*, 1963, 56, 829-833.
- Dinsmoor, J. A. A quantitative comparison of the discriminative and reinforcing functions of a stimulus. *Journal of Experimental Psychology*, 1950, 40, 458-472.
- Doll, T. J. and Thomas, D. R. Effects of discrimination training on stimulus generalization for human subjects. *Journal of Experimental Psychology*, 1967, 75, 508-512.
- Dukhanyil, A. and Lyons, J. E. The effect of overtraining on behavioral contrast and the peak shift. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 253-263.
- Duncan, B. and Fantino, E. The psychological distance to reward. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 23-34.
- Dysart, J., Marx, M. H., McLean, J., and Nelson, J. A. Peak shift as a function of multiple schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1974, 22, 463-470.
- Ellis, W. R. Role of stimulus sequences in stimulus

- discrimination and stimulus generalization. *Journal of Experimental Psychology*, 1970, **83**, 155-163.
- Emurian, H. H. and Weiss, S. J. Compounding discriminative stimuli controlling free-operant avoidance. *Journal of the Experimental Analysis of Behavior*, 1972, **17**, 249-256.
- Ernst, A. J., Engberg, L., and Thomas, D. R. On the form of stimulus generalization curves for visual intensity. *Journal of the Experimental Analysis of Behavior*, 1971, **16**, 177-180.
- Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Freeburne, C. M. and Taylor, J. E. Discrimination learning with shock for right and wrong responses. *Journal of Comparative and Physiological Psychology*, 1952, **45**, 264-268.
- Frieman, J. and Thomas, D. R. A peak shift resulting from a chained reinforcement schedule. *Psychonomic Science*, 1970, **18**, 315-316.
- Gerry, J. E. Peak shift on the tonal frequency continuum: The effects of extinction and punishment. *Psychonomic Science*, 1971, **23**, 33-34.
- Gibbon, J., Berryman, R., and Thompson, R. L. Contingency spaces and measures in classical and instrumental conditioning. *Journal of the Experimental Analysis of Behavior*, 1974, **21**, 585-605.
- Gormezano, I. and Kehoe, E. J. Classical conditioning: Some methodological-conceptual issues. In W. K. Estes (Ed), *Handbook of learning and cognitive processes: conditioning and behavior theory*, Vol. 2. Hillsdale, New Jersey: Lawrence Erlbaum, 1975. Pp. 143-179.
- Grusec, T. The peak shift in stimulus generalization: equivalent effects of errors and noncontingent shock. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 239-249.
- Gutman, A. Positive contrast, negative induction, and inhibitory stimulus control in the rat. *Journal of the Experimental Analysis of Behavior*, 1977, **27**, 219-233.
- Guttman, N. Generalization gradients around stimuli associated with different reinforcement schedules. *Journal of Experimental Psychology*, 1959, **58**, 335-340.
- Guttman, N. Effects of discrimination formation on generalization measured from a positive-rate baseline. In D. Mostofsky (Ed), *Stimulus generalization*. Stanford: Stanford University Press, 1965. Pp. 210-217.
- Guttman, N. and Kalish, H. I. Discriminability and stimulus generalization. *Journal of Experimental Psychology*, 1956, **51**, 79-88.
- Hanson, H. M. Effects of discrimination training on stimulus generalization. *Journal of Experimental Psychology*, 1959, **58**, 321-334.
- Hearst, E. Discrimination learning as the summation of excitation and inhibition. *Science*, 1968, **162**, 1303-1306.
- Hearst, E. Contrast and stimulus generalization following prolonged discrimination training. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 355-363.
- Hearst, E., Besley, S., and Farthing, G. W. Inhibition and the stimulus control of behavior. *Journal of the Experimental Analysis of Behavior*, 1970, **14**, 373-409.
- Hearst, E. and Jenkins, H. M. Sign-tracking: The stimulus-reinforcer relation and directed action. *Animal Learning and Behavior*, 1974, **2** (Monograph Supplement, 49 pp.)
- Hearst, E., Koresko, M. B., and Poppen, R. Stimulus generalization and the response reinforcement contingency. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 369-380.
- Hearst, E. and Sidman, M. Some behavioral effects of a concurrently positive and negative stimulus. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 251-256.
- Heinemann, E. G. and Chase, S. On the form of stimulus generalization curves for auditory intensity. *Journal of Experimental Psychology*, 1970, **84**, 483-486.
- Henderson, R. W. Compounds of conditioned fear stimuli. *Learning and Motivation*, 1975, **6**, 28-42.
- Hendry, D., Switalski, R., and Yarcower, M. Generalization of conditioned suppression after differential training. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 799-806.
- Herrnstein, R. J. Aperiodicity as a factor in choice. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 179-182. (a)
- Herrnstein, R. J. Secondary reinforcement and the rate of primary reinforcement. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 27-36. (b)
- Holz, W. C., Azrin, N. H., and Ayllon, R. Elimination of behavior of mental patients by response-produced extinction. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 407-412.
- Honig, W. K. Predictions of preference, transposition, and transposition-reversal from the generalization gradient. *Journal of Experimental Psychology*, 1962, **64**, 239-248.
- Huff, R. C., Sherman, J. E., and Cohn, M. Some effects of response-independent reinforcement on auditory generalization gradients. *Journal of the Experimental Analysis of Behavior*, 1975, **23**, 81-86.
- Jenkins, H. M. Generalization gradients and the concept of inhibition. In D. I. Mostofsky (Ed), *Stimulus generalization*. Stanford: Stanford University Press, 1965. Pp. 55-61.
- Kelleher, R. T. and Gollub, L. R. A review of positive conditioned reinforcement. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 543-597.
- Klein, M. and Rilling, M. Generalization of free-operant avoidance behavior in pigeons. *Journal of the Experimental Analysis of Behavior*, 1974, **21**, 75-88.
- Konorski, J. *Integrative activity of the brain*. Chicago: University of Chicago Press, 1967.
- Lawrence, D. H. and Festinger, L. *Deterrents and reinforcement: The psychology of insufficient reward*. Stanford: Stanford University Press, 1962.
- Lewis, M. Effect of effort on value: An exploratory study of children. *Child Development*, 1964, **35**, 1337-1342.
- Lewis, M. Psychological effect of effort. *Psychological Bulletin*, 1965, **64**, 183-190.
- Logan, F. A. *Incentive: How the conditions of reinforcement affect the performance of rats*. New Haven: Yale, 1960.

- Logan, F. A. and Wagner, A. R. *Reward and punishment*. Boston: Allyn and Bacon, 1965.
- LoLordo, V. M. Positive conditioned reinforcement from aversive situations. *Psychological Bulletin*, 1969, **72**, 193-203.
- LoLordo, V. M. and Hart, C. L. The effects of compounding discriminative stimuli that control variable-interval limited-hold avoidance. *Psychonomic Science*, 1972, **29**, 147-148.
- Long, C. K. and Allen, J. D. Stimulus compounding in the pigeon. *Bulletin of the Psychonomic Society*, 1974, **4**, 95-97.
- Mariner, R. W. and Thomas, D. R. Reinforcement duration and the peak shift in postdiscrimination gradients. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 759-766.
- Melnick, J. The effects of summated stimuli with retarded children. *Journal of Experimental Child Psychology*, 1972, **14**, 277-286.
- Meltzer, D. and Freeman, B. J. Maintenance of response summation under conditions of minimum stimulus intensity. *Psychonomic Science*, 1971, **22**, 287-289.
- Meltzer, D. and Hamm, R. J. Response summation in the pigeon. *Bulletin of the Psychonomic Society*, 1976, **7**, 515-518.
- Meltzer, D. and Masaki, M. A. Stimulus parameters producing response summation. *Psychonomic Science*, 1972, **29**, 155-157.
- Meltzer, D. and Niebuhr, B. R. Additive and suppressive summation with a chain schedule. *Journal of Experimental Analysis of Behavior*, 1974, **22**, 519-524.
- Miller, L. Compounding of pre-aversive stimuli. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 293-299.
- Miller, L. Compounding of discriminative stimuli from the same and from different modalities. *Journal of the Experimental Analysis of Behavior*, 1971, **16**, 337-342.
- Miller, L. and Ackley, R. Summation of responding maintained by fixed-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1970, **13**, 199-203.
- Miller, N. E. Studies of fear as an acquirable drive: I. Fear as motivation and fear reduction as reinforcement in the learning of new responses. *Journal of Experimental Psychology*, 1948, **38**, 89-101.
- Mowrer, O. H. On the dual nature of learning: a re-interpretation of "conditioning" and "problem solving". *Harvard Educational Review*, 1947, **17**, 102-148.
- Mowrer, O. H. *Learning theory and behavior*. New York: Wiley, 1960.
- Overmier, J. B. and Schwarzkopf, K. H. Summation of food and shock based responding. *Learning and Motivation*, 1974, **5**, 42-52.
- Overmier, J. B. and Seligman, M. E. P. Effects of inescapable shock upon subsequent escape and avoidance responding. *Journal of Comparative and Physiological Psychology*, 1967, **63**, 28-33.
- Pavlov, I. P. *Conditioned reflexes*. New York: International Publishers, 1927.
- Pierrel, R. and Sherman, J. G. Generalization of auditory intensity following discrimination training. *Journal of the Experimental Analysis of Behavior*, 1960, **3**, 313-322.
- Pierrel, R. and Sherman, J. G. Generalization and discrimination as a function of  $S^D$ - $S^A$  intensity difference. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 67-71.
- Purtle, R. B. Peak shift: A review. *Psychological Bulletin*, 1973, **80**, 408-421.
- Reberg, D. and Black, A. H. Compound testing of individually conditioned stimuli as an index of excitatory and inhibitory properties. *Psychonomic Science*, 1969, **17**, 30-31.
- Rescorla, R. A. Pavlovian conditioned inhibition. *Psychological Bulletin*, 1969, **72**, 77-94.
- Rescorla, R. A. Informational variables in Pavlovian conditioning. In G. H. Bower (Ed), *The psychology of learning and motivation*, Vol. 6. New York: Academic Press, 1972.
- Rescorla, R. A. and LoLordo, V. M. Pavlovian inhibition of avoidance behavior. *Journal of Comparative and Physiological Psychology*, 1965, **59**, 406-412.
- Rescorla, R. A. and Solomon, R. L. Two-process learning theory: Relationship between Pavlovian conditioning and instrumental learning. *Psychological Review*, 1967, **74**, 151-182.
- Rescorla, R. A. and Wagner, A. R. A theory of Pavlovian conditioning: Variations on the effectiveness of reinforcement and non-reinforcement. In A. H. Black and W. Prokasy (Eds), *Classical conditioning II*. New York: Appleton-Century-Crofts, 1972. Pp. 64-99.
- Richards, R. W. Stimulus generalization and delay of reinforcement during one component of a multiple schedule. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 303-309.
- Riess, D. Pavlovian phenomena in conditioned acceleration: Stimulus summation. *Conditioned Reflex*, 1969, **4**, 257-264.
- Rilling, M. Stimulus control and inhibitory processes. In W. K. Honig and J. E. R. Staddon (Eds), *Handbook of operant behavior*. Englewood Cliffs, New Jersey: Prentice-Hall, 1977. Pp. 432-480.
- Rudolph, R. L. and Honig, W. K. Effects of monochromatic rearing on spectral discrimination learning and the peak shift in chicks. *Journal of the Experimental Analysis of Behavior*, 1972, **17**, 107-111.
- Rudolph, R. L., Van Houten, R., and Maddox, J. Conditional discrimination training and peak shifts in the pigeon. *Psychonomic Sciences*, 1971, **23**, 255-256.
- Schlosberg, H. The relationship between success and the laws of conditioning. *Psychological Review*, 1937, **44**, 379-394.
- Sheridan, C. L., Levinson, D. M., and Cristal, R. M. Effects of fixed-ratio training on subsequent preference for the reinforcer. *Psychonomic Science*, 1965, **2**, 263-264.
- Sidman, M. Conditioned reinforcing and aversive stimuli in an avoidance situation. *Transactions of the New York Academy of Sciences*, 1957, **19**, 534-544.
- Sidman, M. and Boren, J. J. The relative aversiveness of warning signal and shock in an avoidance

- situation. *Journal of Abnormal and Social Psychology*, 1957, 55, 339-344.
- Sloane, H. N. Stimulus generalization along a light flicker rate continuum after discrimination training with several S's. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 217-222.
- Solomon, R. L. The influence of work on behavior. *Psychological Bulletin*, 1948, 45, 1-40.
- Spence, K. W. The differential response in animals to stimuli varying within a single dimension. *Psychological Review*, 1937, 44, 430-444.
- Spence, K. W. *Behavior theory and conditioning*. New Haven: Yale, 1956.
- Stevenson, J. G. Stimulus generalization: the ordering and spacing of test stimuli. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 457-468.
- Terrace, H. S. Wavelength generalization after discrimination learning with and without errors. *Science*, 1964, 144, 78-80.
- Terrace, H. S. Behavioral contrast and the peak shift: effects of extended discrimination training. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 613-677. (a)
- Terrace, H. S. Discrimination learning and inhibition. *Science*, 1966, 154, 1677-1680. (b)
- Terrace, H. S. Discrimination learning, the peak shift, and behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 727-741.
- Terrace, H. S. Evidence for the innate basis of the hue dimension in the duckling. *Journal of the Experimental Analysis of Behavior*, 1975, 24, 79-87.
- Thomas, D. R. The effects of drive and discrimination training on stimulus generalization. *Journal of Experimental Psychology*, 1962, 64, 24-28.
- Thomas, D. R. and Burr, D. E. S. Stimulus generalization as a function of the delay between training and testing procedures: a reevaluation. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 105-109.
- Thomas, D. R. and Lyons, J. Further evidence of a sensory-tonic interaction in pigeons. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 167-171.
- Thomas, D. R., Ost, J., and Thomas, D. Stimulus generalization as a function of the time between training and testing procedures. *Journal of the Experimental Analysis of Behavior*, 1960, 3, 9-14.
- Thomas, D. R. and Setzer, J. Stimulus generalization gradients for auditory intensity in rats and guinea pigs. *Psychonomic Science*, 1972, 28, 22-24.
- Thomas, D. R. and Williams, J. L. A further study of stimulus generalization following three-stimulus discrimination training. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 171-176.
- Thompson, D. M. Punishment by  $S^D$  associated with fixed-ratio reinforcement. *Journal of the Experimental Analysis of Behavior*, 1965, 6, 189-194.
- Trapold, M. A. and Overmier, J. B. The second learning process in instrumental learning. In A. H. Black and W. F. Prokasy (Eds), *Classical conditioning II. Current theory and research*. New York: Appleton-Century-Crofts, 1972. Pp. 427-451.
- Tsai, S. Y. and Weiss, S. J. A further application of composite-stimulus control in additive summation. *Bulletin of the Psychonomic Society*, 1977, 9, 169-172.
- Van Houten, R., O'Leary, K. D., and Weiss, S. J. Summation of conditioned suppression. *Journal of the Experimental Analysis of Behavior*, 1970, 15, 117-121.
- Van Houten, R. and Rudolph, R. Summation of punishment suppression. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 117-121.
- Verhave, T. The functional properties of a timeout from an avoidance schedule. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 391-422.
- Weisman, R. G. Some determinants of inhibitory stimulus control. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 443-450.
- Weisman, R. G. Factors influencing inhibitory stimulus control: differential reinforcement of other behavior during discrimination training. *Journal of the Experimental Analysis of Behavior*, 1970, 14, 87-91.
- Weisman, R. G. and Litner, J. S. Positive conditioned reinforcement of Sidman avoidance behavior in rats. *Journal of Comparative and Physiological Psychology*, 1969, 68, 597-603.
- Weisman, R. G. and Ramsden, M. Discrimination of a response-independent component in a multiple schedule. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 55-64.
- Weiss, S. J. Summation of response strengths instrumentally conditioned to stimuli in different sensory modalities. *Journal of Experimental Psychology*, 1964, 68, 151-155.
- Weiss, S. J. Attentional processes along a composite stimulus continuum during free-operant summation. *Journal of Experimental Psychology*, 1969, 82, 22-27.
- Weiss, S. J. Discrimination training and stimulus compounding: consideration of nonreinforcement and response differentiation consequences of  $S^A$ . *Journal of the Experimental Analysis of Behavior*, 1971, 15, 387-402.
- Weiss, S. J. Stimulus compounding in free-operant and classical conditioning: A review and analysis. *Psychological Bulletin*, 1972, 78, 189-208.
- Weiss, S. J. Additive summation by stimulus compounding irrespective of behavioral contrast during discrimination training: An investigation with positive reinforcement and avoidance schedules. *Animal Learning and Behavior*, 1975, 3, 359-369.
- Weiss, S. J. Stimulus control of free-operant avoidance: The contribution of response and incentive relations between multiple-schedule components. *Learning and Motivation*, 1976, 7, 476-516.
- Weiss, S. J. The isolation of stimulus-reinforcer associations established with multiple schedules. *Animal Learning and Behavior*, 1977, 5, 421-429. (a)
- Weiss, S. J. Free-operant compounding of low-rate stimuli. *Bulletin of the Psychonomic Society*, 1977, 10, 115-117. (b)
- Weiss, S. J. and Emurian, H. H. Stimulus control during the summation of conditioned suppression. *Journal of Experimental Psychology*, 1970, 85, 204-209.
- Weiss, S. J. and Van Ost, S. L. Response discriminative and reinforcement factors in stimulus control of performance on multiple and chained schedules of reinforcement. *Learning and Motivation*, 1974, 5, 459-472.

- Weiss, S. J. and Wiltz, R. A. Jr. Response enhancement and suppression through compounding discriminative stimuli signalling free-operant avoidance. *Proceedings of the 80th Annual Convention of the American Psychological Association*, 1972, 7, 757-758.
- Wheatley, K. L. and Thomas, D. R. Relative and absolute density of reinforcement as factors influencing the peak shift. *Journal of the Experimental Analysis of Behavior*, 1974, 22, 409-418.
- Wildemann, D. G. and Holland, J. G. The effect of the blackout method on acquisition and generalization. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 73-80.
- Wilkie, D. M. The peak shift and behavioral contrast: Effects of discrimination training with delayed reinforcement. *Psychonomic Science*, 1972, 26, 257-258.
- Williams, B. A. The failure of stimulus control after presence-absence discrimination of click-rate. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 23-27.
- Wiltz, R. A. Jr. Combined-stimulus control as a function of the response rate controlled by the absence of the single stimuli. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 541-551.
- Wiltz, R. A. Jr. Combining stimuli signalling response-dependent food and shock. *Journal of the Experimental Analysis of Behavior*, 1974, 22, 363-370.
- Wolf, M. M. Some effects of combined S<sup>D</sup>s. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 343-347.
- Yarczower, M., Dickson, J. F., and Gollub, L. R. Some effects on generalization gradients of tandem schedules. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 631-639.
- Yarczower, M., Gollub, L. R., and Dickson, J. F. Some effects of discriminative training with equated frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 415-423.
- Yarczower, M., Gollub, L. R., and Dickson, J. F. Stimulus control and the response-reinforcement contingency. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 561-563.

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